Spatial and Temporal Characteristics of Paleoseismic Features in the Southern Terminus of the New Madrid Seismic Zone in Eastern Arkansas

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Investigations Undertaken

Recently conducted aerial surveys, field surveys, and trenching revealed the existence of several liquefaction features (sand blows) and related linear features as far as south of Marianna, Arkansas. This is more than 100 kilometers from the currently active segments of the New Madrid Seismic Zone. We believe that these earthquake-induced features are significant for the following reasons: (1) They are at considerable distance from present-day earthquake activity. The implication of this is that they either represent an earthquake source region not previously recognized, or that they were caused by an earthquake(s) of very large magnitude generated by the New Madrid Seismic Zone. (2) These features have very large dimensions (~110 meters by 60 meters), resembling historic and prehistoric sand blows in the immediate vicinity of the New Madrid Seismic Zone. (3) Potentially, detailed investigation of these features will have important implications for earthquake risk mapping in the central United States. (4) The sand blows near Marianna are likely to provide important constraints on the magnitude of the characteristic earthquake in the region and the southern terminus of the New Madrid Seismic Zone.

Preceded the fieldwork, satellite images, aerial photographs, and soil maps were studied to locate sites having characteristics similar to ones that were confirmed of being sand blows in the region. Eight of these sites were found in the areas north, west, and southwest of Marianna, Arkansas. Four investigative field trips were conducted to perform geological, geophysical, and soil studies. This was necessary to reduce the number of sites to only two to be trenched as required by the statement of work for this project. The field trips were conducted on the following dates: Oct. 13th, Oct. 22nd - 23rd, Oct 24th, and Oct.31- Nov 3. During these field trips the following was accomplished:

(1) Evaluation of 8 sites north, west, and southwest of Marianna, Arkansas, where sandy surface deposits likely to be sand blows had been previously identified. These sites are in close proximity (with 5 km radius) of the confirmed sand blows that were identified in previous study (Al-Shukri, *et. al*., 2000; Lemmer *et. al*., 2001).

(2) Selection of 3 sites, namely Johnson's Farm, Daytona Beach, and Nancy 2, for Ground Penetrating Radar (GPR) geophysical survey to characterize the shallow subsurface below these sites. The main task of the GPR survey was to prospect for sand dikes and to delineate area of sandy deposits;

(3) High-resolution GPR geophysical survey of the 3 sites.

(4) 3-D processing and interpretation of geophysical data.

(5) Excavation of two perpendicular trenches through sand deposit at Johnson's Farm, targeting geophysical signatures interpreted as sand dikes and a tree stump.

(6) Documentation of the sedimentological and structural characteristics of Quaternary deposits exposed in the trenches.

(7) Reconnaissance for earthquake-induced liquefaction features along portions of L'Anguille and St. Francis Rivers and the St. Francis Floodway east of Marianna.

Results

Geophysical Analysis

High-resolutions GPR surveys were completed at three sites (Figure 1). The primary goal of these surveys was to delineate the shallow subsurface through a 3-dimensional imaging of the upper 3 meters below these sandy areas. The main target was to map the contact between the sand and the silt (or clay) layer. This will allow the determination of the thickness of the sand and to locate discontinuities or disturbances to this contact. This, in return, will help identify potential sites for sand dykes and locate other anomalies such as tree stumps. GPR surveys also help identify sites that might be the result of fluvial deposits, such as old channels, which were suspected of being sand blows.

For Johnson's Farm site, 33 parallel profiles were surveyed, each with a length of 26 meters. 0.5 meters spacing between profiles was used. This makes the dimensions of the area covered to be 16 x 26 meters. Each profile was set to have more than 5,400 scans. Figure 2 shows a 3-D projection of the GPR data for this site. Notice the sharp discontinuity between the sand and silt layers. Also clearly visible is the anomalous change in the thickness of the sandy layer. The 3-D high-resolution analysis indicates that the anomalous area is about 3 meters in diameter with a maximum depth of about 1 meter. The same analysis predicted the location of a tree stump that is close to the anomaly. According to these results, the trench locations were selected to excavate the anomaly and the tree stump. We believe that the GPR is cost effective because it was not just accurate in finding the anomaly, but also the tree stump was found in the predicted location.

At the Daytona Beach site 15 profiles were collected each with a length of 80 meters. These profiles were directed in the E-W direction. The cotton crop in this filed was not yet harvested which restricted the profiles to follow the cotton trenches only. Each

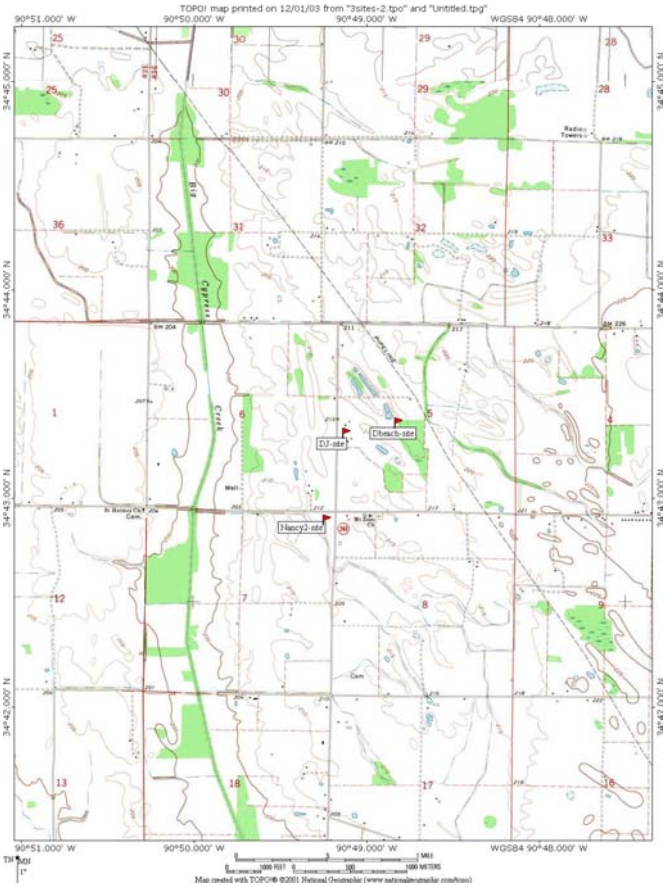

Figure 1. Topographic map showing the locations of the sites that were investigated in this study

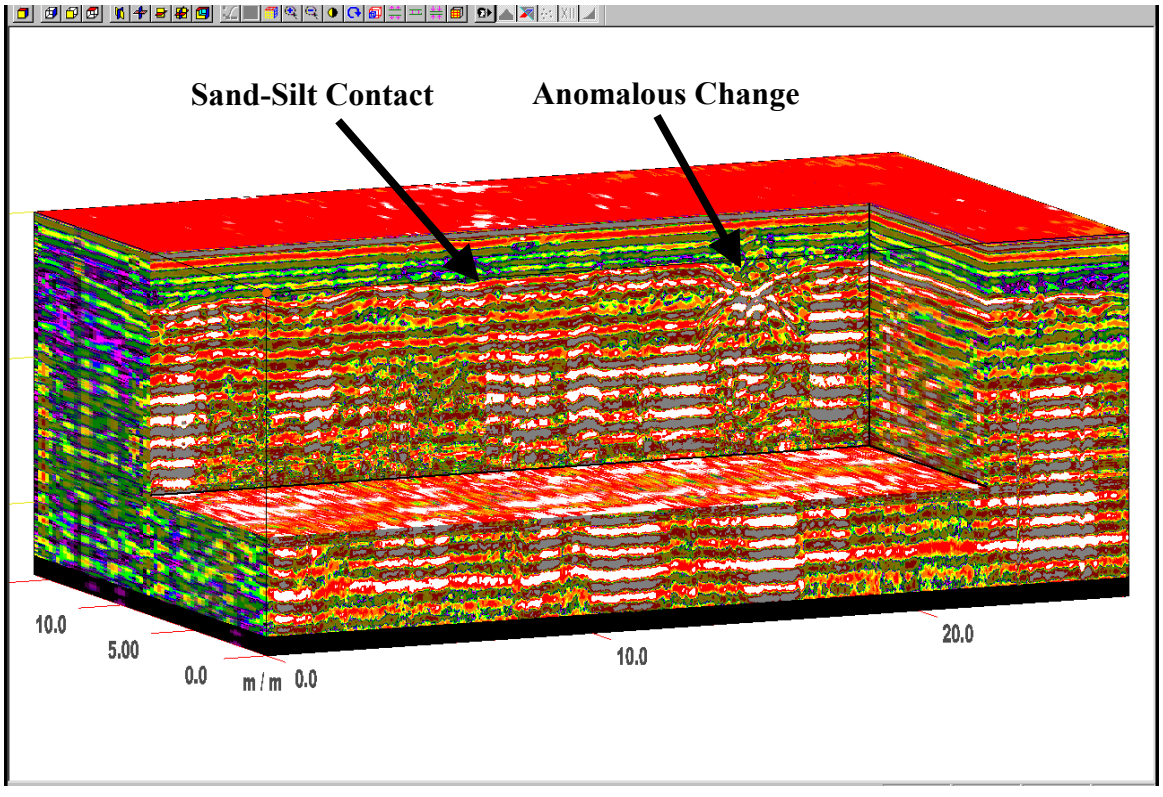

Figure 2. Three-dimensional image of the GPR data at the Johnson's Farm site.

profile consists of more than 8,100 scan. The most visible feature in the 3-D image of the data is the sharp dipping of the sand-silt contact to the east (Figure 3). At the east end of the profile, this contact abruptly lost its sharpness. This indicates a disturbance to this contact had taken place and possibly caused a mix up to the subsurface material. The research team elected to extend the GPR profiles to the east before trenching, however, the continuous rain and the high water saturation in the area prevented that.

The GPR surveying at Nancy 2 was mainly conducted to locate a tree stump that was previously discovered in earlier work (Al-Shukri, *et. al*., 2000). We sought the stump to collect datable material (radiocarbon dating) for this sand blow. GPR data helped identified the exact location of the trench and the approximate location of the tree stump. We were unable to trench the site due to the difficulties that were unanticipated (the this section at the end of this report).

Excavation at Johnson's Farm

As described above, the geophysical survey at Johnson's Farm imaged subsurface disturbances interpreted as sand dikes and a tree stump. Two, 1.3-m-deep, perpendicular trenches were excavated to intersect some of the more prominent disturbances. Exposed in the trenches, a 1-m thick, iron-stained, sand deposit is underlain by a gray, silt deposit containing iron and manganese nodules. The sand deposit is fairly massive and coarsens upward from silty, fine sand to medium sand. This deposit does not resemble sand blows in the New Madrid region, which are composed of one or more layers of sand that fine upward. The weathering characteristics of the deposits at this site suggest that they are Wisconsin in age. This is consistent with geologic mapping of Early Wisconsin valley train deposits in the area (Saucier, 1994).

No sand dikes were found in either of the trenches. However, soft-sediment deformation structures including large diapir-like intrusions of silt and lobes of sand occur in the vicinity of the imaged disturbances (Figures 4 and 5). Discontinuous bedding in the sand appears to be folded along the flank of one of the silt intrusions. Although unusually large, these deformation structures resemble load casts. Most load casts are thought to be syn-depositional and related to density instability in layered sediment (Allen, 1982). However, some load casts have been attributed to earthquake-induced liquefaction of sediment (Sims, 1975). In the New Madrid region, small load casts associated with sand dikes and sills are thought to be related to earthquake-induced liquefaction (Tuttle, 1999). However, no sand dikes or sills were found at the Johnson Farm. Therefore, the soft-sediment deformation structures at the Johnson site more likely formed as a result of density instability, although an earthquake origin cannot be ruled out.

A near-surface disturbance interpreted as a tree stump was found to be just that. The disturbance was intersected by both trenches (see Figure 4; southern end of trench log) and found to be a root cast, containing a partially decomposed tree stump, extending into the top of the sand deposit. A sample (W1) of the tree stump was collected. The ability to identify tree stumps with GPR has important implications for citing trenches and locating datable material in future paleoseismology investigations.

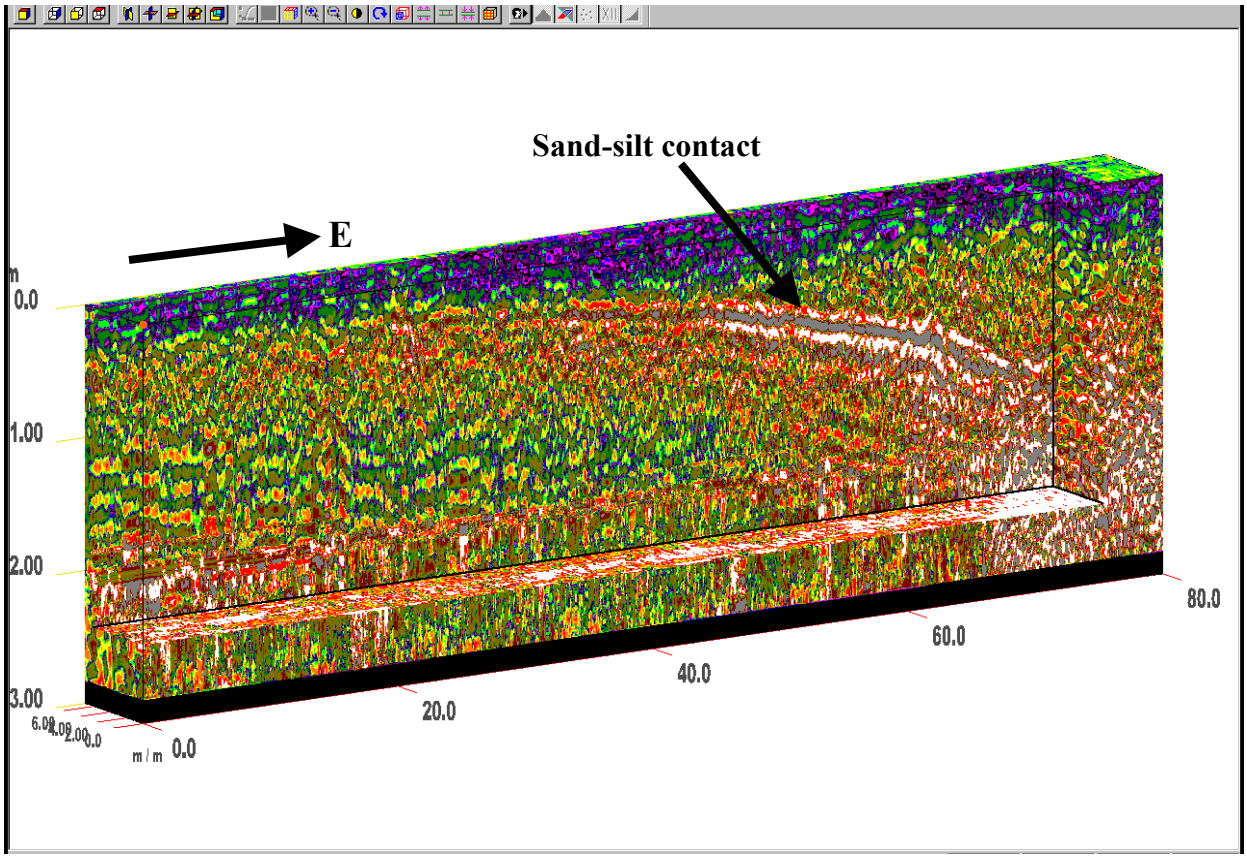

Figure 3. Three-dimensional image of GPR data at the Daytona Beach Site.

Figure 4. Photograph of the Daytona Beach Site. The view is looking east

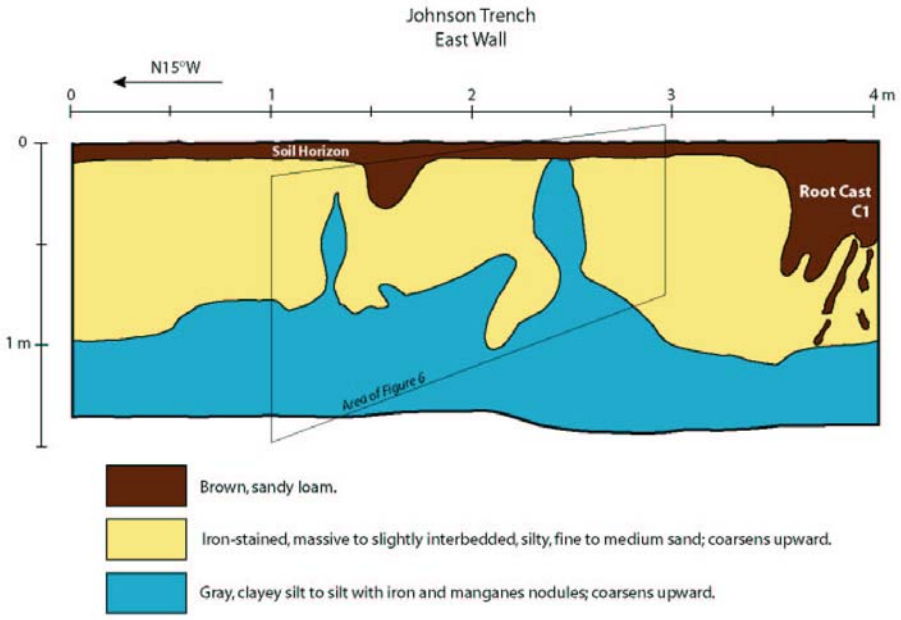

Figure 5. Log of eastern wall of trench at Johnson's Farm located southwest of Marianna, Arkansas, showing soft-sediment deformation of silt and sand deposits. Area of Figure 6 shown by rectangle. C1 indicates location of charcoal sample. Log by M. Egan, H. Al-Shukri, and M. Tuttle.

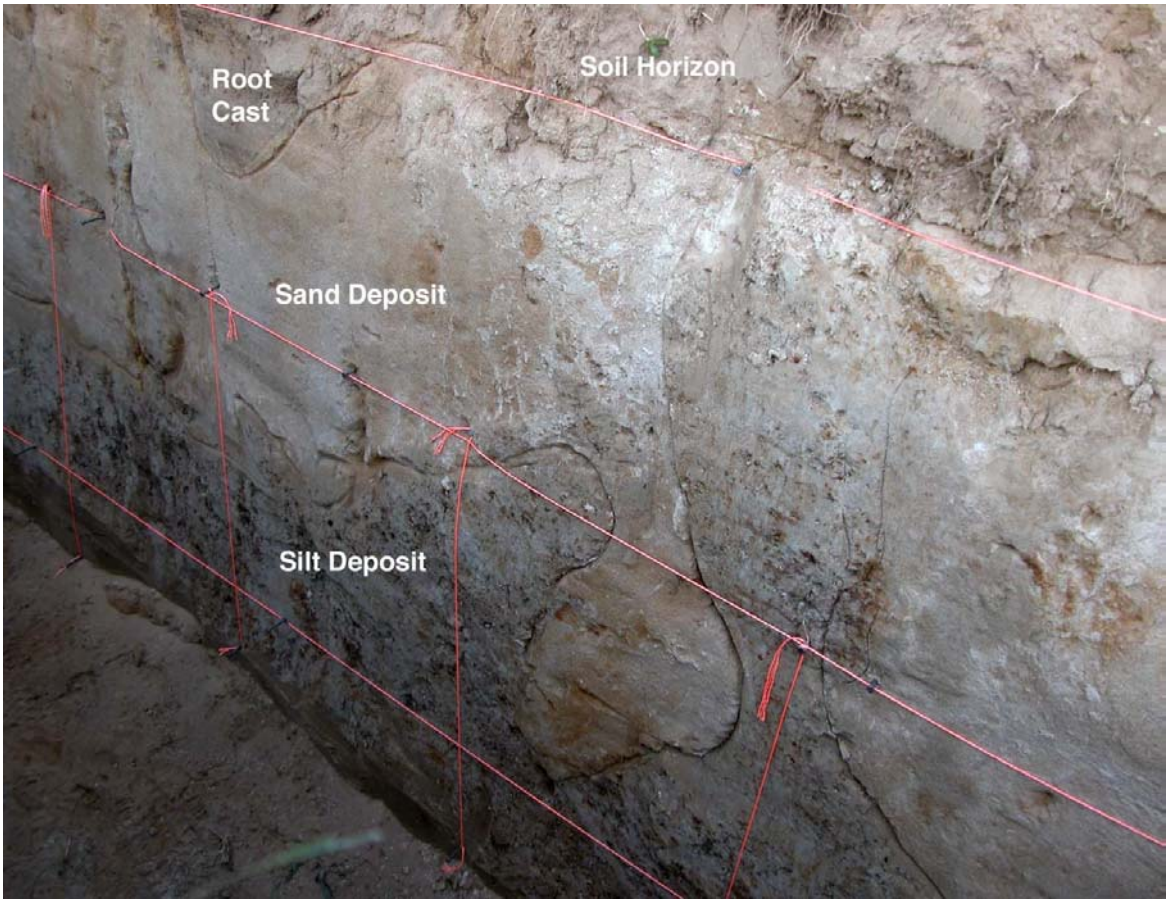

Figure 6. Image of the eastern wall of Johnson's Farm Trench. Log of the trench is shown in Figure 5.

River Reconnaissance

We conducted reconnaissance for liquefaction features along 2 km of the St. Francis River west and downstream of the Huxtable pumping station, 4 km on St. Francis Floodway south of Rt. 79, and 3 km of L'Anguille River between the St. Francis Floodway and the St. Francis River. The area searched is located 3-10 km east-southeast of Marianna. The surficial geology of the area has been mapped as Holocene point bar and channel deposits of the Mississippi River (Saucier, 1994).

Along the St. Francis River, cutbank exposure of deposits is fairly poor. The exposed deposits are composed of interbedded silt and sand that contain pieces of metal farming equipment and therefore must be quite young. Along L'Anguille River, there are two terrace levels and exposure of deposits is fairly good. The lower terrace, about 8-10 m in height, is underlain by young, interbedded silt and sand, similar to deposits along the St. Francis River. The higher terrace, about 10-12 m in height, is underlain by ripple, cross-bedded sand and laminated silt and sand that appear more weathered, and therefore are probably older, than deposits of the lower terrace. In some locations, thick layers of sand occur within and at the base of the older sections. Where these sand layers are overlain by silt, conditions appear suitable for the formation of liquefaction features; but none were found. There is almost no exposure of deposits along the St. Francis Floodway, except south of the Rt. 79 bridge. Here, cutbanks are 8-10 m in height and expose very fine sand overlying thick layers of silt and cross-bedded sand. Again conditions seem suitable for liquefaction yet no features were found. Perhaps the deposits are too young or the exposure too poor for us to have found liquefaction features along the 9 km of river cutbank searched.

At a site (SFF-1) near the southern termination of the St. Francis Floodway, we collected a sample of twigs and leaves from a silt layer about 12 m below the top of the cutbank and 1 m above the water level. Radiocarbon dating of the sample would help to establish the age of the deposits in which we did not find liquefaction features. If the deposits are at least 1,000 years old, it may be worthwhile to conduct more river reconnaissance to determine whether or not earthquakes centered in the New Madrid seismic zone or in the vicinity of Marianna have induced liquefaction in this area.

Unanticipated Problems

Due to a rainy summer, the fall harvest was later than usual and many of the fields where we had planned to work still had crops on them in late October and early November. Rainstorms prevented us from conducting geophysical survey as scheduled. The survey had to be rescheduled for a later date. In addition, we had difficulty reaching farmers and property owners to request permission for excavating 2 of the 3 selected sites.

Non-Technical Summary

Liquefaction is a common phenomenon in unconsolidated near-surface sediments in moderate to large earthquakes in which water-saturated sediment, when shaken, behaves as a liquid rather than a solid. This liquefied sand is often extruded onto the surface as a sand blow. Ancient seismic events can therefore be recognized by the presence of sand

blows, which themselves may be radiocarbon dated to determine the age of the earthquake. The nature and extent of paleoseismic features in northeastern Arkansas and adjacent areas of the New Madrid Seismic Zone is well known. The extent of these features south of the NMSZ, however, is not well investigated. Fieldwork by the PI's has identified paleoseismic features approximately 100 km south of the southern terminus of the NMSZ, the most distant features identified to date. This study was proposed to characterize the features by geological and geophysical methods such that the nature and age of the features can be determined. Results from this study are expected to have important implications for the magnitude of the characteristic earthquake and seismic hazard assessment and mapping in eastern Arkansas.

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